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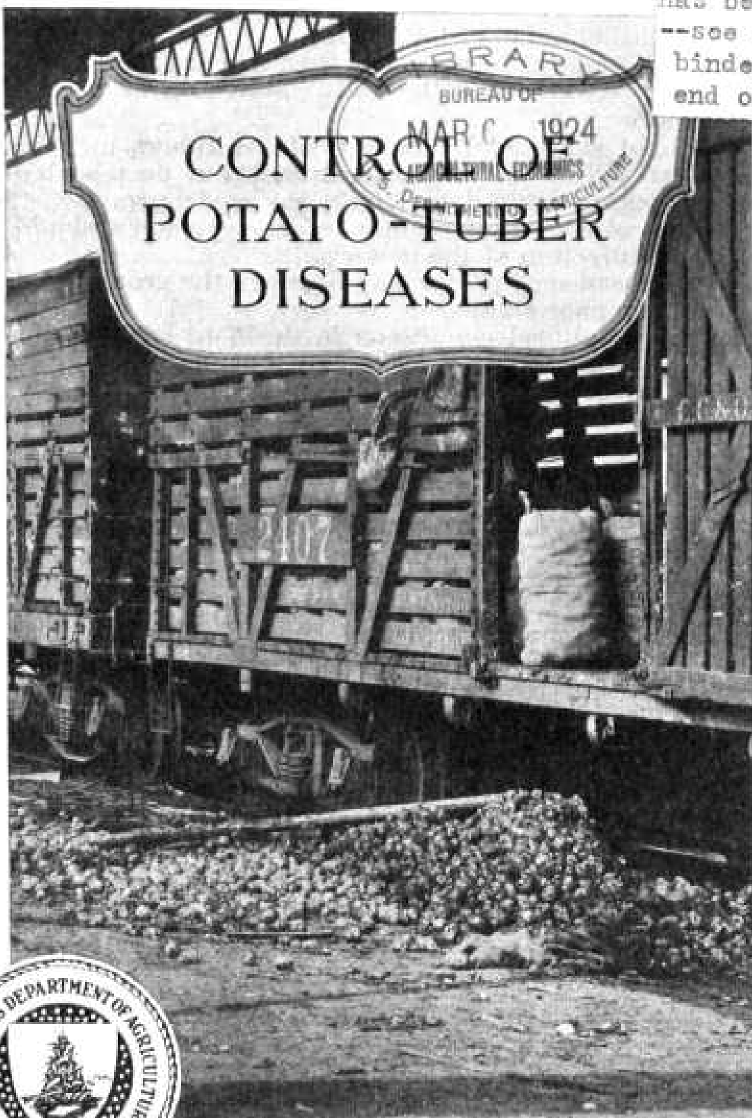
CONTROL OF POTATO-TUBER DISEASES



THIS BULLETIN discusses potato-tuber diseases and methods of control. Potato diseases controllable by spraying are treated in Farmers' Bulletin 1349, while the diseases concerned in seed-potato improvement will be considered in another Farmers' Bulletin.

Tuber diseases tend to decrease yield and lower the market value of the stock.

Most potato diseases are due to parasites which either live in the soil or are carried in or on the tuber, or both.

Slight superficial infection of the tubers may be gotten rid of by proper treatment, but deep-seated injuries render potatoes unfit for seed purposes.

Diseased seed tubers may infect clean soil and add to the infection of the new crop.

Diseased seed pieces may decay in the ground and produce poor stands.

Good cultural conditions in the field seem to increase resistance and to lower predisposition to certain diseases.

Sulphur treatment of the soil for common scab has been successful in some localities.

New potatoes, especially when immature, should be handled very carefully to avoid injuries.

Bruised and skinned tubers are especially subject to decay.

Tubers with an apparent decay should not be put in storage, as the disease may spread in the bin.

Potatoes not disposed of immediately, particularly seed stock, require good storage conditions with proper temperature, humidity, and aeration.

Some tuber-borne diseases can not be detected in the tuber, and their eradication must be accomplished in the field.

Many potato diseases affect both the tubers and the tops and must be combated in the bin as well as in the field. Some are exclusively tuber troubles, and therefore control measures consist chiefly of tuber selection and tuber treatment.

This bulletin is a revision of and supersedes Farmers' Bulletin 544, Potato-Tuber Diseases.

Washington, D. C. Issued January, 1924

CONTROL OF POTATO-TUBER DISEASES.

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CONTENTS.

POTATO-TUBER DISEASES IN THEIR RELATION TO PRODUCTION AND MARKETING.

POTATOES seriously affected by diseases apparent upon examination are unsalable. The presence of a large percentage of decaying or otherwise affected tubers in the newly harvested crop may lead to its rejection by inspectors at the point of loading or to failure to meet requirements of the United States potato grades, with attendant discount of sale price or failure to bring any price at all. Such stock when shipped may decay badly in transit as well as in storage and sell at a discount, or it may be rejected at destination. Naturally this situation affects the income of the producer as well as the total output of potatoes. It also tends to increase the cost to the consumer without any gain whatever for the grower.

The difficulties which confront the owner of a diseased potato crop are by no means confined to the market phase of the industry. They are in this case merely quite apparent and immediate. A far more serious and more permanent menace to the farmer and the national industry lies in the use of diseased tubers for seed. Many potato diseases are caused by living parasitic organisms which are capable of destroying plant tissues. The destructive action of these parasites when they are introduced into the soil may involve all parts of the potato plant, the seed tuber, the tops, and the new tubers as well. Very often seed-piece decay, poor germination, uneven stands, and low yields may be traced to the use of diseased tubers. The new crop when affected becomes in turn a source of infection for subsequent crops if used for planting or may be partially or wholly unmarketable.

Aside from the direct infection of the new crop, the use of diseased tubers for seed leads also to the contamination of the soil, which frequently makes it impossible to raise sound potatoes on the

same land for many years. It is true that some of our cultivated land is heavily infested with various parasites and will produce diseased crops even if perfectly healthy tubers are planted. Yet some new soils are relatively free from infection and should by all means be guarded against contamination with various dangerous diseases. Potato culture is constantly extending into districts where this crop has not previously been grown. This is most notable in the newly irrigated parts of the West, in the recently deforested portions of Minnesota, Wisconsin, and Michigan, and in the trucking districts of the Gulf States. In each case the seed supply has to be brought from outside, and in altogether too many instances no attention is paid to the elimination of disease. Meanwhile planting diseased tubers on such soils is not only likely to ruin the immediate crop but to render the potato industry on this land unprofitable for years to come. It should be clearly realized that many serious potato diseases once introduced into the soil are not easily exterminated.

The consequences of neglect to eliminate disease are particularly grave in sections where growers specialize in seed-potato production. The growers in a large part of the territory lying in the Southern, South-Central, and Western States prefer to plant seed potatoes grown in Maine, Vermont, New York, Michigan, Wisconsin, Minnesota, and other States near our northern border. Consequently a large trade has grown up and potatoes are annually shipped long distances for planting. The importance of good seed is being recognized throughout the country more and more every year, while sources of high-grade seed are relatively very few. The producer of disease-free seed potatoes helps to keep new districts from infection and wisely avails himself of the opportunity to build up a substantial and lasting trade.

The responsibility of seed dealers in this matter is likewise very large. The interest of the local dealer in the continued maintenance of productivity in a region should be as great as that of the farmer, and none of them ought knowingly to risk the introduction of pests that might threaten the prosperity of their section. Yet because of lack of knowledge and failure to appreciate fully the importance of the matter this has often been done.

The elimination of potato-tuber diseases thus constitutes a subject of general interest and importance. The measures for their control, however, should be in strict conformity with the nature of the trouble. Therefore a clear conception of the peculiar characteristics of various diseases is necessary for their successful combat. This bulletin gives a brief description of each of the important potato-tuber diseases with reference to the most practicable control measures. It is to be hoped that such information as is presented herewith may clarify the potato-disease situation to the grower and the dealer and enable them to understand the various troubles and prevent them if possible or to seek the assistance of a specialist whenever troubles become perplexing or go beyond the possibilities of first-aid measures.

GENERAL TYPES OF DISEASES.

Certain potato diseases, such as mosaic, streak, leaf-roll, and other similar maladies, are not apparent in the tubers. Although they

represent a group of very serious troubles and are transmissible through the seed tubers from one generation to another, the freedom of a stock from this type of disease can be determined only by inspection of the growing crop. Furthermore, the control measures are also confined at present exclusively to field operations, such as roguing the infected plants or spraying for insects which carry the disease in the field. Maladies of this group do not constitute primarily tuber diseases and therefore are not discussed in this bulletin.

Among the diseases which are apparent in tubers are a few the causes of which are not definitely known. A few are distinctly physiological, due to unfavorable climatic or soil conditions. With these exceptions potato-tuber diseases are caused by minute parasites, of which the principal ones are fungi and bacteria. On the basis of the effect of the destructive activities of these parasites, tuber diseases may be divided into three principal groups. Certain fungi and bacteria are capable of causing a complete and progressive destruction of the potato-tuber tissues. This type of trouble is known as tuber rot or tuber decay. In other cases parasitic organisms invade the vascular tissues of the tubers, causing little or no decay. In the third instance parasites confine their detrimental work to the superficial layers of the tuber and cause diseases of the skin or malformations. Some of the organisms are known to cause more than one type of disease, as, for instance, to invade the vascular tissues and also to produce a progressive decay.

PRINCIPAL MEASURES OF CONTROL.

Our present methods of combating potato-tuber diseases are by no means perfect. Yet in spite of their distinct limitations, when properly applied they afford an effective means of raising better crops and of preventing their subsequent spoilage in cellars, in warehouses, and in transit. A waste of time and money and much disappointment may readily be avoided if a clear understanding is obtained as to the conditions under which a given control measure is effective. No tuber treatment can to any extent lessen the infection which originates from the soil. If the soil is infested, some soil treatment or soil management should be employed whenever feasible to stamp out the infestation. Tuber treatments have proved to be effective for only a few skin diseases and in superficial infections present on the surface of the potato. Deep-seated parasitic invasions, such as those taking place in decays or in infection of the water vessels, can not be reached by any of the treatments now known. The only means of preventing a possible spread of such diseases is to discard the infected tubers. A discussion of control measures follows.

GOOD STORAGE AND TRANSIT CONDITIONS.

The diseases which may develop under favorable conditions of storage and transit are primarily the various tuber decays and certain physiological troubles. Of the skin diseases, only silver scurf is known to make considerable headway during the resting period of the tubers.

Three factors are essential to keep storage and transit diseases in check—good ventilation, proper air moisture, and proper tempera-

ture. Stored potatoes should be given a thorough circulation of air. Lack of aeration may cause black-heart. It is also liable to result in a considerable accumulation of moisture in the bin pile, thus favoring decay. The air, however, should not be too dry, as this leads to an excessive shrinkage of the tubers and weakens their vitality and resistance to decay. The best temperature for the storage of potatoes is between 36° and 40° F. Temperatures that are too low may bring about freezing injury, while those above 40° F. favor the progress of storage diseases. Decay may develop even in apparently sound tubers, since ordinarily potatoes are placed in storage without previous disinfection and therefore may carry parasitic germs on the surface.

Adequate ventilation, humidity, and temperature are attained by proper construction and management of the storage houses and cars used for shipment, which are described in Farmers' Bulletin 847, Potato Storage and Storage Houses, and in Farmers' Bulletin 1091, Protection of Potatoes from Cold in Transit—Lining and Loading Cars.

USE OF SELECTED SEED.

The control of many tuber diseases is made more effective by the seed-plat and field-inspection measures practiced in connection with up-to-date seed-potato improvement methods. See Farmers' Bulletin 1332, Seed Potatoes and How to Produce Them. It is also important that there be a rigid bin selection to rid the stock of all serious tuber diseases and injuries. Both procedures are essential for the growing of healthy crops. Tubers showing decay, vascular discoloration, net necrosis, or old deep bruises are more or less a menace to the following crop and therefore are not fit for seed purposes. These defects may at least contribute to seed-piece decay or weaken the vitality of the plants. Nonparasitic troubles, such as black-heart or freezing injury, may produce a similar effect on the vigor of the potato plant. Small tubers, such as may be used to plant whole, are as good as large tubers, provided they are produced by healthy plants. However, when the source of the stock is not known the use of small seed tubers should be avoided, as they may have come from mosaic or leaf-roll hills or from plants which have died prematurely because of other diseases.

CAREFUL HANDLING.

The potato skin when intact constitutes a good protection against the invasion of the tuber by various parasites which cause tuber rots. Cuts and bruises, on the contrary, offer an easy entrance for parasitic organisms. Tubers should not be handled like stones. They are living things, and their skin, even though very effective as a protective covering, is delicate and easily broken. Bruises may be either superficial or internal, deep or shallow, extending over a large surface or only as narrow slits. These various injuries may be caused by digging implements, by handling potatoes with steel shovels or forks, by careless throwing, heavy loading, and other similar rough treatment. Much of the spoilage in cellars, in warehouses, and in transit may be avoided by careful handling of tubers whether at the time of digging or in loading and unloading. In

some cases cut and bruised tissues dry out rapidly, and the wound is sealed by a grayish granular deposit of starch and later by a brown layer of cork. Quite often, however, fungi and bacteria enter the wounds and cause decay (fig. 1). Leak, which is a very destructive decay in the San Joaquin delta of California, originates for the most part at the wounds made by digging forks or where knobs are broken off. Slimy soft-rot, causing large losses in the early crop, is greatly favored by excessive skinning and subsequent bruising of the immature tubers. Wounded potatoes may at least harbor parasitic germs, and this may bring about seed-piece decay when such tubers are planted in moist soil. Even when not infected, potatoes that are bruised, cut, or split, while suitable for food, result in large losses in paring, and their presence lowers the grade and market value of a shipment.

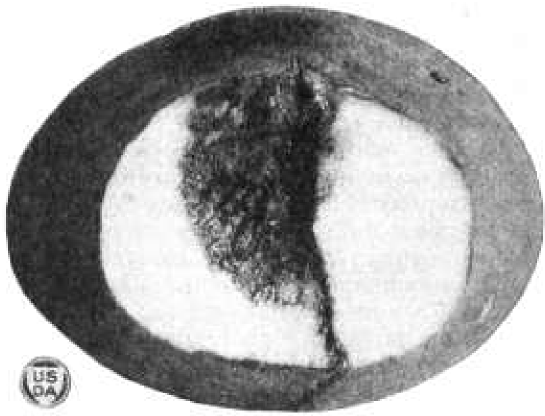

FIG. 1.—A potato showing decay following a mechanical injury.

SEED TREATMENTS.

It is advisable to treat seed potatoes before planting when new land is being used or when a heavy infestation of the old land with disease is not certain. Disinfection, however, may be regarded as a factor in raising better crops only in so far as it destroys parasites on the outer layers of the tubers. In the case of decays or vascular discolorations other methods of control must be used.

Many disinfectants have been tried, but only two substances have so far proved to be of superior value—formaldehyde and corrosive sublimate. In some localities rolling the seed pieces in sulphur is practiced, but the value of this procedure in preventing seed-piece decay or other troubles has not been proved.

It is very important that the disinfecting solution be correctly prepared and rightly used and that treated potatoes receive proper care. Whenever these rules are observed, no serious troubles from treatment need be anticipated. If sprouts are too large at the time of disinfection, they may be injured or broken off, but new ones are formed immediately. If a solution is made too strong, however, the tuber itself may be severely injured. Likewise, if after treatment cut pieces are left in barrels or in piles for several days before planting, their vitality may be weakened either through drying and heating or through molds and decays.

FORMALDEHYDE SOLUTION.

The standard method of formaldehyde treatment which has been in common use for many years consists of soaking the potatoes for two hours in a solution made of 1 pint of 40 per cent formaldehyde

in 30 gallons of water. As a disinfectant for seed potatoes formaldehyde has generally been preferred to corrosive sublimate, which is a dangerous poison, corrodes metals, and requires extreme care in handling. Formaldehyde has proved to be particularly satisfactory for surface disinfection against black-leg and common scab, though, according to some reports, not so effective for Rhizoctonia black scurf. However, since the standard method is a cumbersome and time-consuming procedure, two modifications of it recently have been suggested.

One of these modifications consists of shortening the time of soaking from 2 hours to 30 minutes. The same cold solution as in the standard method, in the proportion of 1 pint of 40 per cent formaldehyde to 30 gallons of water, is used. To cover the potatoes with burlap for about an hour following the soaking adds to the efficiency of the treatment. This method has been tried in certain localities, and in some instances the results have been found satisfactory, though as compared with the longer treatment it appears to be somewhat less effective.

Another modificaton has been worked out by the Iowa Agricultural Experiment Station. According to this method the time of exposure may be reduced to only 2½ minutes, but the solution must be warm, about 122° F., and its strength must be doubled. This procedure requires a specially constructed apparatus for maintaining the proper temperature of the solution, which is described in detail in publications of that station. To cover the tubers with a tarpaulin or burlap for an hour after treatment adds to the efficiency of this method. It is reported to be as effective as the corrosive-sublimate and the formaldehyde treatments of the standard formulas. Wherever either of these modifications has been tried and found satisfactory it may be used to advantage.

Formaldehyde solution, whether cold or hot, does not corrode metal and is not a dangerous poison. Potatoes treated with it may be used for food with perfect safety. The diluted solution does not lose its strength on standing and if covered may safely be kept for a few days or weeks.

CORROSIVE SUBLIMATE.

The effectiveness of corrosive sublimate or mercuric chlorid as a disinfectant for potatoes has been known for a long time. However, not until it was pointed out that it is more efficient than the standard formaldehyde treatment in controlling Rhizoctonia black scurf has it come into more general use. The original formula prescribes a solution of 1 part of corrosive sublimate in 1,000 parts of water or 4 ounces in 30 gallons of water and soaking for 1½ hours.

It has been suggested by some that the time of exposure may be shortened to 30 minutes, as in the case of formaldehyde treatment. The control of disease may be somewhat less perfect, but the results are said to be satisfactory enough to justify this saving of time.

Corrosive sublimate goes into solution very slowly in cold water, and it should, therefore, be first dissolved in a small volume of hot water. The dissolving may be still further hastened by the addition of a quantity of ammonium chlorid equal to that of the corrosive sublimate used. The solution should be prepared and used in wooden, enamel, or concrete containers. While not injurious to the

hands, it is a deadly poison when taken internally by man or animals. Potatoes treated with it are unfit for food or feeding.

The corrosive-sublimate solution grows weaker from use, in extreme cases losing as much as one-fourth of its strength during a single treatment. The loss is greater when sacks instead of crates are employed for dipping and when dirty potatoes instead of clean ones are treated. It is therefore advisable to add some freshly dissolved corrosive sublimate after each batch of potatoes in order to preserve approximately the original strength of the solution. The quantity which is necessary for this varies from one-third to 1 ounce to each barrel, depending upon the cleanness of the potatoes and the kind of container in which they are dipped. Enough water should be added along with this each time to bring the solution up to its original volume. This correction of the strength of the solution may be repeated four times, after which the disinfectant may be used twice more, and then, because the composition of the old solution has become uncertain, it is best to discard it and prepare a new one.

METHODS OF SEED TREATMENT.

Two principal methods are used for treating large quantities of potatoes with cold solutions of either formaldehyde or corrosive sublimate—the barrel method and the vat method. When the barrel method is employed several barrels, according to the quantity of potatoes to be handled, are set on a slightly elevated platform, each having a well-fitted plug in a hole near the bottom. The barrels are filled with potatoes and the disinfecting solution is poured over them until the tubers are completely covered. After immersion for the required length of time, the solution is drawn off and poured into another barrel. The number of barrels is increased in proportion to the quantity of potatoes to be treated.

Another method is to use a large wooden vat or trough into which the potatoes in sacks or crates are lowered by a rope and pulley and later hauled out, drained, and dried on slatted racks. A rectangular tank 6 feet long, 3 feet wide, and 30 inches deep, inside dimensions, will accommodate 20 bushels at each treatment and if filled to a depth of 18 inches will hold approximately 200 gallons of the solution. Approximately 6⅔ pints of the 40 per cent formaldehyde or 27 ounces of mercuric chlorid will be required to make the respective solutions of the standard strength. If about 3½ ounces of freshly dissolved corrosive sublimate are added after each of the first four dippings to restore the strength of the disinfectant and enough water to restore the original volume and if the solution is used two additional times, then about 40 to 41 ounces of mercuric chlorid will suffice to treat 120 bushels of potatoes. After this the solution should be completely renewed.

Some growers practice exposure of seed potatoes to the light for several weeks before planting, to permit greening and sprouting. When this is done the treatment should be applied first, as otherwise the sprouts will be injured and germination retarded.

It is advisable to treat potatoes before cutting. After cutting, the seed pieces may be sprinkled with flowers of sulphur or gypsum to facilitate drying and separation from each other in planting.

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Knives used in cutting treated seed potatoes should be disinfected every time a badly diseased tuber is cut, and the tuber itself should be discarded. It is advisable to keep an extra knife in a strong formaldehyde solution, so that it may be used while the contaminated knife is being disinfected.

SOIL TREATMENTS.

The limitations of soil treatment at present are still greater than those of seed treatment. The soil-management problem as related to the control of diseases is a very complex one, involving many factors, some of which are not known and a number beyond control.

It is generally advisable to avoid planting potatoes for a period of years on fields which are known to be heavily infested with potato disease germs. Other crops not related to potatoes, preferably nonroot crops, may be planted meantime. No case is known in which parasitic organisms have been completely eradicated from the soil by means of crop rotation, but a substantial decrease in the severity of infection may be expected in some cases.

As regards concrete measures to be applied in specific cases, some definite information is available only in connection with the control of common scab. The New Jersey Agricultural Experiment Station has worked out a method whereby sulphur treatment of the soil under New Jersey conditions is a paying proposition for those growers who are much troubled by this disease. Particularly good results are reported from the so-called inoculated sulphur. It has been noted that scab developed very little or not at all in acid soils, and the application of sulphur is intended to increase the soil acidity. When sulphur is inoculated with certain specific bacteria its action in this respect is much more pronounced. Publications of the New Jersey station give detailed instructions as to the use of its method, although some details, as, for example, the quantity of sulphur required for a given locality, may best be worked out locally. The effect of sulphur on succeeding crops in connection with locally practiced crop rotations should also be considered. Green manuring, as, for example, the plowing under of a rye crop, has also been found to reduce the injury by scab resulting from soil infection. The beneficial effect of green manuring has been attributed to the fact that it renders the soil more acid and thus inhibits the growth of the scab organisms.

DETAILED CHARACTERS OF POTATO-TUBER DISEASES.

Some potato maladies are primarily or even exclusively tuber diseases, such as scab and certain physiological disorders. In these the tops are either not affected at all or only in an indirect way through a weakened vitality of the whole plant. A great many troubles, however, are common to both the tubers and the tops and should be combated in the field as well as by means of tuber selection and treatment. In this bulletin a detailed description will be given only of the tuber symptoms of these diseases.

DECAYS.

Decomposition of potato tubers when caused by microscopic parasites may develop in the form of a dry rot, or a wet rot, or a distinctly soft and slimy decay. Fungi may cause dry, wet, or even watery rots, depending on conditions and on the fungus involved, but they do not cause slimy decays. Slimy soft rots are caused by bacteria. Both fungi and bacteria enter the tuber mostly through the stems or through wounds. In some other cases infection takes place at the openings in the skin of the tuber, known as lenticels, and also through tender tissues at the eyes.

FIG. 2.—A typical form of potato black-leg decay in the East.

BLACK-LEG TUBER ROT.

This disease (figs. 2 and 3) is common in practically all parts of the country. It is a bacterial disease and affects both the tops and tubers. It derives its name from the fact that the lower portions of the diseased stems usually turn black. Seed potatoes when infected with this disease serve as the principal source of the infection in the field. Very little is known at present about the overwinter-

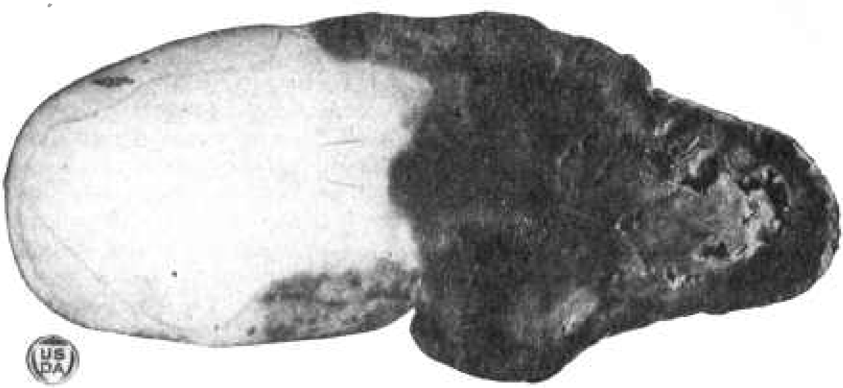

FIG. 3.—A type of black-leg decay of the Netted Gem potato.

ing of the causal organism (*Bacillus phytophthorus* Appel) in the soil. New tubers contract the disease principally from mother plants through the stolons. In very moist places, or under irrigation in the West, healthy tubers may become infected from the sides when lying too close to the decaying tubers. Potatoes in the ground decay very rapidly and become soft and slimy throughout. (See

"Slimy soft-rot.") Freshly decayed portions may be white or only slightly colored and cheesy or buttery in consistency, but gradually turn black and slimy as the decomposition goes on. In storage, black-leg is confined in typical cases to the center of the tuber, which becomes hollowed and black with a layer of slimy lining. In the case of long western varieties, the decay may develop as a stem-end rot, externally resembling other stem-end rots (fig. 3). Decomposing parts have a disagreeable, foul odor. A mild infection of the tuber with black-leg may result only in the discoloration of the vascular ring at the stem end.

Control.—The only method of control in the field is to rogue all the diseased plants as soon as they appear. In the East the most severe attack of black-leg takes place during the early part of the season. In the irrigated sections of the West new cases of infection may be observed throughout the summer nearly up to digging time. After the harvest all the diseased tubers should be discarded, as they may start considerable decay in the bin. No tuber showing any black-leg decay should be used for seed. Treatment either with formaldehyde or corrosive-sublimate solution is regarded advisable to disinfect the surface of tubers which may have become contaminated with black-leg bacteria through contact with the diseased tubers in handling or in storage.

FIG. 4.—A potato affected with slimy soft-rot.

SLIMY SOFT-ROT.

Slimy soft decays (fig. 4) of potatoes are quite common and may be either of a primary or secondary nature. They are caused by bacteria, usually of the *Bacillus carotovorus* group. As a disease of primary nature, slimy soft-rot attacks mainly the early southern immature crop during the hot part of the year, particularly when potatoes, badly bruised or skinned, are loaded while overheated and shipped under poor ventilation. The decaying parts turn into a creamy slime with a repulsive odor. If the affected potatoes are spread out and well aired, the decay usually stops. As a secondary trouble it may follow other diseases or injuries, especially late-blight tuber rot and scald or freezing injury. As such it occurs on the late crop from various parts of the country. Slimy soft-rot is not known to affect stems, but it may be a contributing factor in new tuber decay in water-logged soils and in seed-piece decay, causing poor germination when weather conditions are not favorable for germination and growth.

Control.—Measures of prevention consist almost exclusively of thorough drying before packing, careful handling to avoid bruising, and providing proper temperature and ventilation in transportation and storage.

LATE-BLIGHT TUBER ROT.

Late-blight (fig. 5) is one of the most destructive diseases in the New England and North-Central States. Like black-leg, it affects both the tops and the tubers. Similarly, the infection in the field originates from the diseased seed. Unlike black-leg, however, it is not a bacterial disease, but is due to a fungus, *Phytophthora infestans* De By. The new tubers become infected either in the soil through spores washed from the diseased tops or in harvesting through contact with blighted foliage. When late-blight tuber rot develops in the soil it is more or less soft in consistency, partly because of an abundance of moisture but mainly because other organisms, particularly bacteria, follow the work of the late-blight fungus (see "Slimy soft-rot"). When the decay is not complicated by secondary organisms, it is brown in color and spreads irregularly from the surface through the flesh, like the diffusion of a brown stain. Under storage conditions the disease is typically a dry rot, forming irregular sunken patches which under conditions favorable for their development, such as high humidity and temperature, may involve the entire tuber. These patches are usually quite firm, unless secondarily affected by other parasites; and frequently they have a metallic tinge, especially on the border of healthy tissues.

FIG. 5.—A potato affected with late-blight tuber rot.

Control.—Spraying with Bordeaux mixture is absolutely essential for the protection of the crop from late-blight infection. To be successful it must be begun early and done thoroughly, as described in detail in Farmers' Bulletin 1349, Increasing the Potato Crop by Spraying. Tubers showing rot at harvest should not be put in storage. However, the infection is often not apparent at this time, but develops during the winter unless the temperature of the storage cellar is kept just above the freezing point. Affected potatoes should not be used for seed, because they generally fail to germinate, causing broken stands in fields, or because they give rise to diseased plants which act as centers of infection for the entire field. By means of seed tubers the disease is carried to the South Atlantic trucking districts, where it sometimes develops as leaf-blight in the spring, whereas in the North it prevails in late summer.

FUSARIUM TUBER ROT.

Fusarium tuber rot of potatoes (figs. 6 to 10) is caused by a number of closely related molds, or fungi, known as Fusarium. At least one of these fungi also attacks the growing plant and causes the disease known as Fusarium blight or wilt. (See p. 18.)

Tubers borne by blighted plants frequently show merely discoloration in the ring tissue at the stem end, entering through the stolon,

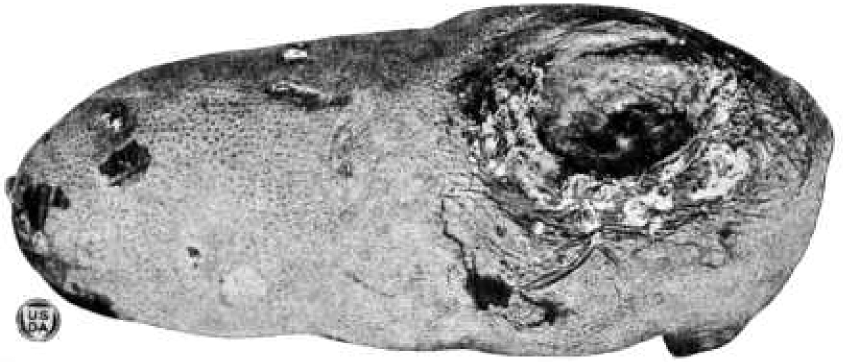

FIG. 6.—A potato affected with Fusarium rot, showing also tufts of the fungous spores.

but they may also show actual rot restricted to the ring tissue or involving all the tissues (fig. 7; see also fig. 14).

Fusarium tuber rot occurs in tubers from practically all potato sections of the United States. Probably most soils are infested with several species of Fusarium, though in some fields one or two species seem to predominate, which is probably due, among other things, to special conditions of air and soil temperature and moisture during the growing season.

FIG. 7.—Stem-end type of the Fusarium infection of potato, originating through the stolon.

Under storage and transit conditions powdery dry-rot is the most common Fusarium tuber rot in western potatoes (fig. 8). Stem-end rot, which predominates in long tubers of the Burbank type, and black field rot, which is especially severe in tubers of the Rural type, are likewise western diseases. The mushy, leaky, grayish type of Fusarium tuber rot is predominantly a southern disease (fig. 10).

Fusarium tuber rot generally is marked by sunken, shriveled, wrinkled, or broken areas occurring on the tuber surface at the stem end, at the lenticels, at the eyes, or anywhere in between. As a rule, these areas are brown to black, and on them may appear masses of whitish, dark, or brightly colored mold.

The tissues underlying such discolored and sunken areas vary in discoloration and consistency, depending on the species causing the rot and the conditions under which the rot develops. The rot may be wet (fig. 9) and jellylike, and even mushy and leaky (fig. 10), or dry and brittle and with or without cavities lined with whitish or brightly colored fluffy or powdery molds. The color of the affected tissues varies from light to dark brown and even black. Sometimes more than one species attacks the same tuber, causing a combination of these types of rot. Fusarium tuber rot is usually dry at low temperatures and wet at high. It never is slimy even when wet and never has a bad odor unless accompanied by other fungi or bacteria.

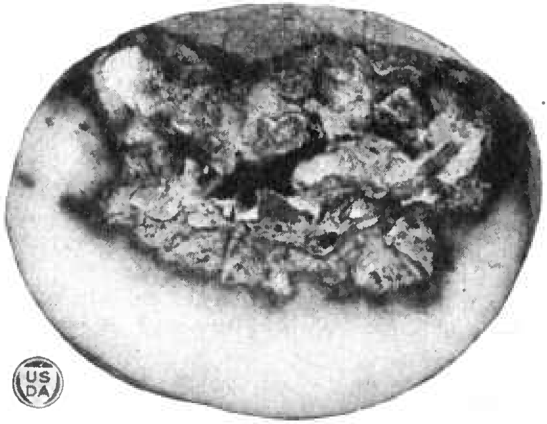

FIG. 8.—A potato affected with Fusarium powdery dry-rot.

In some types of Fusarium tuber rot, as in powdery dry-rot, for example, the fungi have a tendency to rot the center or pith of the tuber faster than the outer or cortical tissues, so that a spot which is scarcely apparent on the surface may be underlain by an extensive wet region or by a rotted dry interior, full of cavities and surrounded by a shell of healthy cortical tissue. In other types the rot progresses more evenly into the tuber, destroying the various tissues at a more or less equal rate. In such rots the dried-out stage often is marked by layerlike dry, tough remnants of the destroyed tissues.

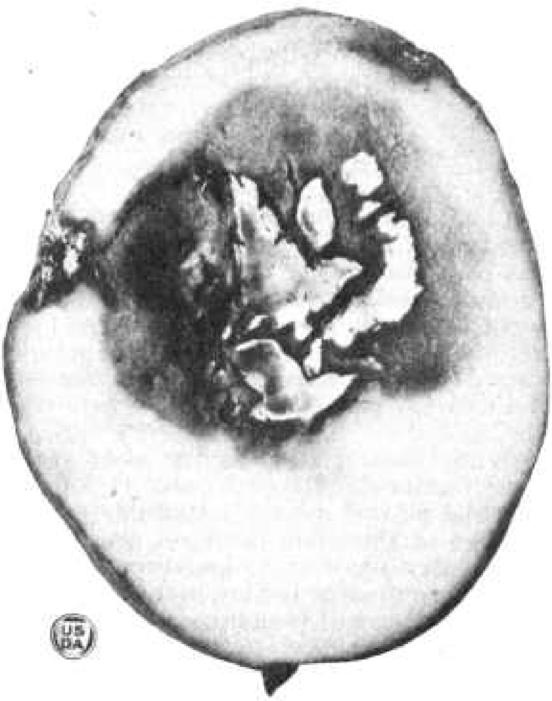

FIG. 9.—A potato affected with a medium wet type of Fusarium rot.

In some types of Fusarium tuber rot the growing tuber may get the disease directly from the soil, the fungus entering through eyes, lenticels, or breaks in the tuber skin. In another type, such as powdery dry-rot, the fungus enters only through breaks in the skin; consequently, this type of Fusarium tuber rot is much more a storage and transit trouble and less a field disease than other types. However, it may also occur in tubers at digging time.

In view of the fact that these fungi occur so universally, it is practically impossible to get tubers which do not bear Fusarium fungi on their surfaces. Since all of them can enter most readily through wounds, Fusarium tuber rot is most frequently found in tubers that have been exposed to freezing temperatures or were carelessly and roughly handled.

Even though these fungi are present on tubers, they can not cause infection unless temperature and moisture conditions are favorable for the germination of the spores and growth of the fungi. None of them can grow nor can their spores germinate if they are not supplied with moisture or if the temperature is 34° F. and below or 102° F. and above. The growth made at temperatures between 41° and 50° F. is very small, yet it really is important because it serves to establish the fungi in the tubers, which may rot very rapidly when brought into higher temperatures. Even at temperatures below 41° F. these fungi are not killed, but can lie dormant for months. Tubers which appear sound when dug or loaded, even though actually infected, may show rot in two weeks if conditions are favorable for the rot, or after months, following a change from unfavorable to favorable moisture and temperature conditions.

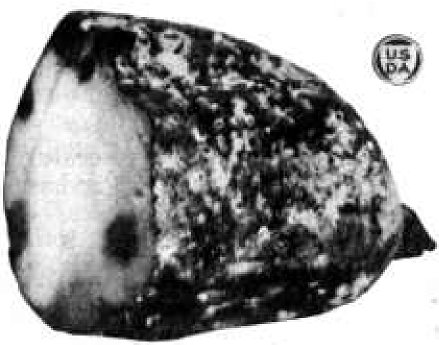

FIG. 10.—A potato affected with an extremely wet or a southern Fusarium tuber rot.

Control.—Since Fusarium tuber rot may proceed from the soil, its control is a very difficult matter. No effective control measures are known for those types of Fusarium tuber rot which are primarily field diseases.

Careful handling during and following the digging of tubers to avoid cuts and bruises is very essential. It is advisable to sort out diseased and frozen tubers before putting a lot into storage.

The storage and transit types of Fusarium tuber rot can be controlled by storing tubers in a dry place at temperatures between 36° and 40° F. This will result in a great reduction in the percentage of Fusarium rot in storage, though it will not entirely check it.

SCLEROTIUM ROT.

This is a disease of the South. (See fig. 11.) The cause is a fungus (*Sclerotium rolfsii* Sacc.) which attacks a great variety of truck crops. It attacks potato vines in the field, producing a rapid decay of the stems at the surface of the ground, or in less serious

eases a gradual wilting and dying of the plants. It also produces a very rapid tuber rot if conditions are favorable. This rot is a white and practically odorless decay in the first stages, but later it takes on a yellowish color. In severe cases the entire contents of the tuber are turned into a liquid or melter stage. The surface of the decaying potatoes is covered with white fungous threads and hard, round, seed-like bodies resembling mustard seed, which usually remain alive for a long time. When scattered in the soil they germinate under favorable conditions and infect new crops.

Control.—No practicable way to exterminate the fungus from the soil is known. Infected tubers, of course, should not be planted. Destruction of diseased plants in the field should be practiced in

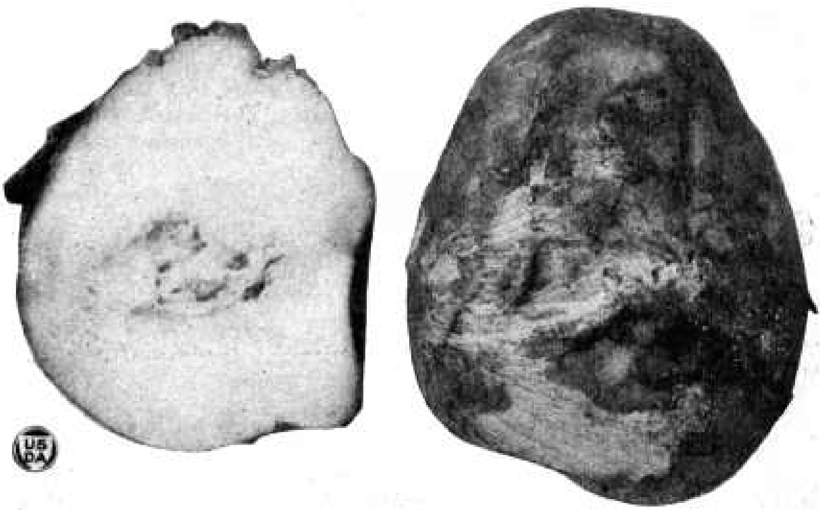

FIG. 11.—A potato showing Sclerotium rot, outside as well as inside.

order to reduce the amount of soil infection. When storing the early southern potatoes is necessary, good storage conditions will check the development of the decay.

LEAK.

Leak[1] (fig. 12) was once considered a disease characteristic of tubers grown in the delta lands of the San Joaquin Valley of California. It now appears to be virtually coextensive with the potato crop of the United States, having been noted in potatoes grown in the eastern, southern, and western potato sections.

The most characteristic symptom of leak is the extremely watery nature of the affected tissues. The water usually is held by the disintegrated tissues, but when pressure is applied a yellowish to brown liquid is given off readily. Another characteristic symptom is the granular nature of the diseased tissues.

Externally the affected tissues appear turgid and may show discoloration ranging from a metallic gray in red varieties to brown

[1] Leak has been reported to be caused by *Pythium debaryanum* Hesse. Other Pythium species or Pythiumlike fungi, Rhizopus species, and Mucor species have also been shown to cause leak or leaklike symptoms.

shades in white and dark skinned varieties. Internally the affected tissues are creamy in color to begin with. Upon cutting, as well as in the later stages of the disease, they soon turn tan or slightly reddish and then become brown and finally inky black. The diseased areas generally are quite sharply set off from the healthy tissue. There rarely is any fungous growth externally or internally, nor are there cavities lined by white or brightly colored molds, as in the soft types of Fusarium rot, which somewhat resemble leak. The colors of leak-affected tissues resemble those of black-heart very much, and frequently leak and black-heart are found in the same tuber. Tissues affected with black-heart, however, are not soft and watery and granular, as are those showing leak.

Tubers become contaminated in the field, where the causal organisms live as soil fungi. Infection takes place during hot weather, and apparently only through wounds, though these need not be visible. Leak frequently is found in tubers affected with sunburn or scald,

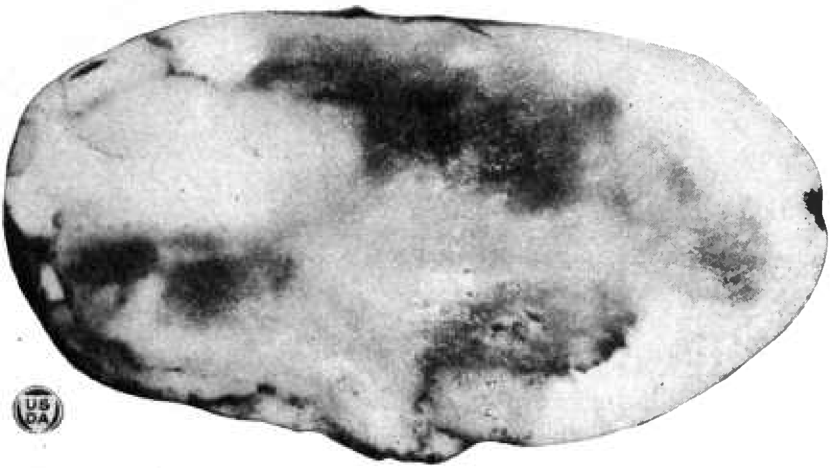

FIG. 12.—A potato affected with leak.

especially when these occur in tubers allowed to lie in or on hot soils after digging. In those potato-growing sections in which the crop is harvested and moved during extremely warm weather (such as the early Idaho and Washington crops and the crop grown in the San Joaquin delta of California), leak is constant and serious. In other sections it seems to occur only if there is abnormally warm weather during the digging, moving, and early storage of the crop.

When infection has once taken place the disease progresses very rapidly and develops in contaminated tubers even in refrigerator cars. Leak may develop in transit or in storage in tubers showing no breaks of the skin and which when taken out of the field appear to be free from the disease. At temperatures between 60° and 90° F. the disease progresses so rapidly that lesions become visible within 36 hours after infection. Freezing temperatures arrest the development of the disease so that the brown to inky black lesions frequently dry out, forming cavities. At low temperatures (32° to 50° F.) leak is frequently followed by Fusarium tuber rot. Under warm conditions (50° F. and higher) leak lesions usually are invaded by bacteria

which check the growth of the organisms causing leak and lead to foul-smelling, sticky, or slimy decays.

Control.—Control involves keeping tubers as cool and dry as possible during harvest and loading and in the early stages of transit and storage and in avoiding breaks of the skin.

JELLY END-ROT.

Burbank potatoes in California and Netted Gems in Idaho are subject to a peculiar decay which gives the affected parts a jellylike consistency (fig. 13). Fusarium is frequently found in such decaying portions of the tuber, especially when the decay ensues at the stem end. However, there is a distinct form of jelly rot which takes place notwithstanding the absence of Fusarium. It occurs usually in those portions of the tuber which are succulent and deficient in starch, such as the pointed ends of the Burbank type and occasionally also the knobs and the eye end. These abnormal watery tissues are attacked by *Fusarium* spp. and also by other fungi, particularly *Rhizoctonia solani*, which are incapable of causing serious decay of a

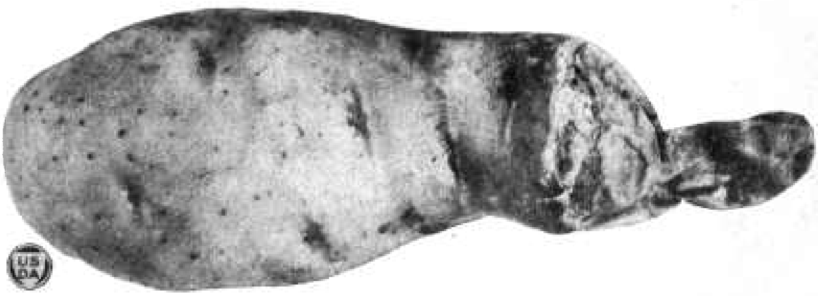

FIG. 13.—A potato affected with jelly end-rot as it appears on pointed-end Netted Gem and Burbank varieties.

normally constituted tuber. Jelly rot has not been reported on round varieties. The true jelly rot develops little, if at all, in storage unless the tubers are infected by parasitic species of Fusarium, and it often dries up soon after the tubers are harvested.

Control.—Prevention of jelly rot depends on the ability of the grower to avoid abnormal pointed-end potatoes. See the paragraph under the heading "Growth cracks and second growth," page 35. This, in turn, depends on proper handling of the irrigation water, in order to give a well-regulated supply of moisture throughout the summer. Tubers which show active stem-end decay in the spring should not be used for seed purposes, as they may harbor secondary invasions of Fusarium and other parasites.

VASCULAR DISEASES.

Tubers frequently show the so-called ring discoloration or browning of the vascular tissues at the stem end. This may be due to a number of causes. A slight and shallow stem-end discoloration may or may not be due to disease. Cultural tests together with microscopic examination frequently reveal that no organisms ever were present in such tissues. On the other hand, absence of ring discolor-

ation does not necessarily indicate that the tuber was produced by a healthy plant or that parasitic organisms are not present in the tuber tissues. A cultural test is the only positive proof of the presence or absence of live fungous parasites in the tuber.

A more prominent browning, beginning at the stem end and extending through a considerable distance toward the eye end, is usually caused by one or more of several parasitic organisms. Most of these organisms are wilt fungi and bacteria, but occasionally other germs penetrate into the water-conducting vessels of the tuber. The blackleg bacterium is principally a decay-producing organism, but occasionally it invades vascular tissues with little, if any, decay of the flesh. Many of the wilt organisms also cause rots of the tubers.

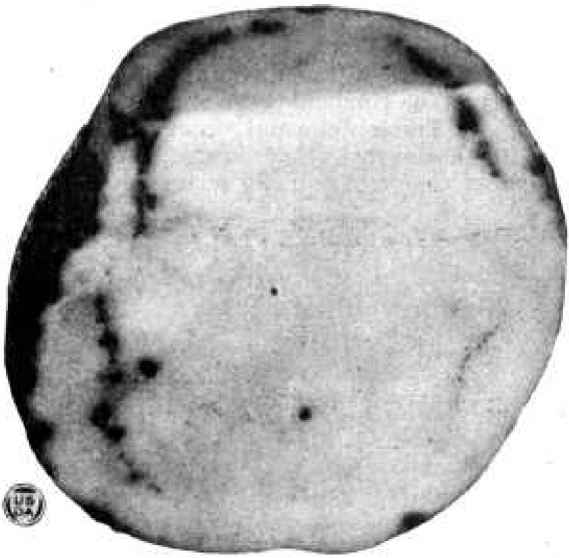

FIG. 14.—A potato showing a discoloration of the vascular ring frequently associated with fungi producing Fusarium blight.

When a potato having vascular infection is cut across it shows a distinct light to dark brown ring a short distance from the outside surface. In severe cases this ring may be traced all the way from the stem end to one or several eyes by which the infection is transmitted to the new plant. This ring discoloration should be distinguished from a brown netting or spotting throughout the flesh of the tuber and not confined to the vessels. Such netting or spotting is characteristic of another group of troubles known as necrosis.

FUSARIUM BLIGHT.

Fusarium blight (fig. 14) is a hot-weather disease and is consequently found only in those potato-growing sections in which high air and soil temperatures prevail during the growing season.

It is primarily a vine disease caused by a species of Fusarium (*F. oxysporum* and possibly others), which is characterized by a blighting or wilting of the vines and is accompanied generally by a browning of the water vessels of the stem and less regularly by a browning of the water vessels of the tuber. Usually the discoloration is confined to the stem end, but at times it extends throughout the length of the tuber and is traceable into the eyes. Sometimes it occurs as a solid ring of discolored tissues and at times as isolated strands in the ring.

Browning or blackening of the ring tissues of tubers is not necessarily proof that the tubers were produced by plants blighted by

Fusarium or that a species of Fusarium is present in the tuber, since other causes are responsible for vascular discolorations.

The discoloration caused by Fusarium blight generally is of the same color as that due to southern bacterial wilt, but usually it is not as moist in appearance. In southern bacterial wilt the affected tissues tend to be softer and when freshly cut may exude grayish sticky globules.

Another ring discoloration, caused by Verticillium, very much resembles that due to Fusarium. However, Verticillium wilt usually occurs only in the cooler potato sections, in which little Fusarium blight is found.

The discolorations characteristic of net necrosis usually affect both the ring and the vascular tissues of the pith and cortex for a considerable distance from the stem end, forming a network of discolored dead fibers, whereas Fusarium blight generally is restricted to the vascular ring at the stem end.

The ring discoloration caused by Fusarium may also be readily confused with the ring type of freezing injury. In both only the ring and adjacent tissues may be affected. Both may occur only at the stem end and both may be rather widely diffused and light or narrow and very dark brown to black. Additional symptoms of freezing injury in the same tuber or in tubers of the same lot or a cultural demonstration of the presence or absence of the fungus sometimes are useful in making a diagnosis.

The discolorations of heat and drought necrosis, although they may be limited to the water vessels, usually occur in the cortex as strands, spots, or dots, and generally are of a golden brown color rather than the brown or black of Fusarium blight.

If temperature conditions are favorable (80° to 95° F.), the species of Fusarium responsible for blight may attack the tissues adjoining the ring tissues and cause tuber rot. This rot frequently is visible externally as small or large sharply sunken metallic-appearing areas at the stem end. The discoloration and decay may involve a considerable portion of the tissues bordering the vascular ring and be soft or dry and full of cavities. Frequently the tissues killed by the blight Fusarium are invaded secondarily by typical tuber-rotting fungi or by bacteria.

Control.—Since Fusarium blight may proceed from the soil or the seed piece, its prevention is a very difficult matter. The present recommendations for control include the rotation of crops and in the western sections experiments with the use of whole seed.

VERTICILLIUM WILT.

This wilt disease is very similar in appearance to Fusarium blight (fig. 14), but its geographic range is more to the north and it is caused by another fungus—*Verticillium alboatrum* Reink. and Berth. It is particularly prevalent in the Northeastern States and on the Pacific slope of the extreme Northwest. The infection of the crop originates either from diseased seed or from infested soil. A healthy plant may contract the disease during the growing season from a neighboring affected plant. Sometimes a grayish mold appears on the wilted stems at the surface of the ground by which this trouble may be distinguished from Fusarium blight in the field.

The ring discoloration of the tuber sometimes differs in intensity from that caused by Fusarium, although this is not always a dependable characteristic. So far as known, the Verticillium wilt fungus does not cause a rot of the tubers.

Control.—The extermination of the affected plants in the field is of greater importance in the seed plat than in the commercial crop. The wilted plants should be dug and destroyed as soon as they can be noticed, together with the new tubers. The adjoining hills, one on each side, also should be destroyed, as in most cases they are likely to be infected. If any affected tuber is found in seed potatoes on cutting, it should be rejected for planting.

BACTERIAL WILT, OR BROWN-ROT.

This type of wilt occurs more or less generally in the Southern States, especially in Florida, and for this reason is also known as the southern bacterial wilt. It is caused by a bacterium (*Bacillus solanacearum* Smith), which attacks growing plants in the field through an invasion of the water-conducting vessels of the stem, in consequence of which the affected plants wilt and die. From the mother plants the infection spreads through the stolons into the new tubers. The infected tubers show a dark-brown ring discoloration. This vascular discoloration is distinguishable from Fusarium blight by the small drops of sticky, milky bacterial exudate which appear on cutting the browned vessels. Furthermore, when conditions are favorable the bacterial ring discoloration quickly develops into the decay known as brown-rot (fig. 15). It usually begins at the stem end and sometimes appears on the surface in the form of grayish patches, but often no decay can be seen on the outside of the tuber. Brown-rot is practically odorless, but takes on a foul odor when followed by slimy soft-rot caused by secondary organisms, which is frequently the case. The brown-rot bacteria also attack a number of other truck crops.

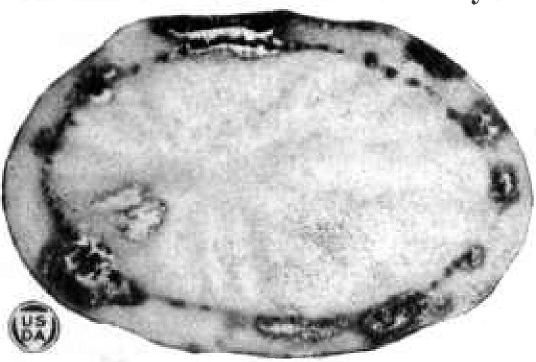

FIG. 15.—A potato affected with brown-rot, or southern bacterial wilt.

Control.—The infected potatoes are likely to decay rapidly; therefore stock which is only mildly affected should be disposed of promptly. Badly affected tubers should be thrown out. No measures are known to prevent infection from the soil. It has been reported that the disease is worse on new soils; therefore it may be advisable to avoid planting potatoes on new ground. When bacterial wilt occurs in the fall crop the potatoes should not be planted. This disease does not occur in the North, where nearly all the seed potatoes used in the South are obtained.

SKIN DISEASES AND MALFORMATIONS.

Some of the potato parasites are not able to penetrate deeply enough into the flesh of the potato tuber to cause a progressive decay or a deep-seated discoloration. Nevertheless, they often cause most serious troubles. Some destroy superficial layers of the cork; others stimulate an abnormal growth of certain outer cells, leading to the formation of outgrowths. These diseases are knowns as scabs, scurfs, and warts. Scab and scurf do not impair the eating qualities of potatoes, though they may greatly lower their market value even as table stock by making them unsightly and by making deep paring necessary, with consequent waste. Potato wart, on the other hand, is a dangerous disease, as it tends to prevent the normal formation of tubers and thus to reduce the yield.

COMMON SCAB.

This disease (fig. 16) is known to exist in every potato-growing section of the United States. It manifests itself in the form of hard, brown, rounded or irregular corky incrustations on the surface of the tuber. The scab spots may be separate or may run together, sometimes to the extent of covering the entire tuber. Common scab varies in appearance and type from deep to shallow and even raised forms. It is caused by the attack of a fungus (*Actinomyces scabies* (Thaxter) Güssow), which is capable of gradual though slow destruction of the cork layers, leading to the formation of corky scabs. Common scab is particularly severe in alkaline soils, but causes little, if any, damage in acid soils. Tender white-skinned varieties appear to be more susceptible to this disease than rough-skinned russet varieties. The causal organism persists in the soil, and the infection of the new crop may come either from the infested soil or from diseased untreated seed. Certain other soil-inhabiting organisms may attack the potato tissues in and around the scab spots, which make the symptoms more complicated and confusing.

FIG. 16.—A potato showing a medium infection with common scab.

The common scab lesions have sometimes been confused with abnormally enlarged lenticels (fig. 17). Under proper conditions of growth these cells remain dormant, but they may enlarge and protrude above the surface of the tuber when potatoes are grown in very wet soils or if the soil becomes water-logged after the tubers are formed. The enlarged lenticels appear as white, soft, pimple-like swellings at first, but later they usually harden and become brown and corky. The tubers so affected are objectionable because of the unsightly appearance of the stock.

Flea-beetle injury, caused by the larva of the flea-beetle, *Epitrix cucumeris* Harr., may also in some cases resemble the external ap-

pearance of the first stages of infection with the common scab fungus. However, on cutting through the flea-beetle pimples or furrows, peculiar tough splinters of corky tissue are found extending perpendicularly into the tuber (fig. 18). Sometimes these splinters are one-fourth inch in length. They are very characteristic of this type of injury. Not infrequently they become infected with Rhizoctonia, which deepens the furrows and the insect punctures. The potatoes having this injury are very objectionable, as they usually require deep paring.

FIG. 17.—A potato showing abnormally enlarged lenticels.

Grub and rodent injuries lead to the formation of large cavities, due to the complete destruction of a portion of the tuber, and seldom can be confused with common scab or other insect and animal injuries. Unlike the common scab spots, these cavities are free from the heavy corky incrustations so characteristic of both the deep and the shallow forms of common scab. Cavities caused by grubs usually have more or less smooth surfaces or are only slightly russeted, while those made by rodents are ridged and furrowed.

FIG. 18.—A potato showing flea-beetle injury.

Control.—Tubers badly disfigured by scab should not be planted. Mildly infected potatoes may be treated with either formaldehyde or corrosive sublimate. If the soil is infested, tuber treatment will not prevent scab. In such cases sulphur may be applied at a rate and in a manner which must be properly worked out for the existing local conditions. Whenever practicable, green manuring may be tried. Crop rotation alone, irrespective of its effect on soil alkalinity, does not tend to

lessen the danger of scab infection. Wood ashes, lime, and stable manure all promote scab and therefore should not be used on the potato crop unless the soil is sufficiently acid to offset the effect of these materials. In the case of neutral or alkaline soils it is best to apply them, if at all necessary, to the crop immediately following potatoes in the rotation system. If no effective soil treatment is available and the soil is infested, the more scab-resistant russet varieties may be substituted for smooth varieties wherever they can be grown and disposed of profitably.

POWDERY SCAB.

The distribution of powdery scab (fig. 19) in the United States is limited to moist cool regions, such as exist in the North, especially in the Northeast, though it has not yet been reported from all localities in these sections. Moreover, its prevalence in these regions varies

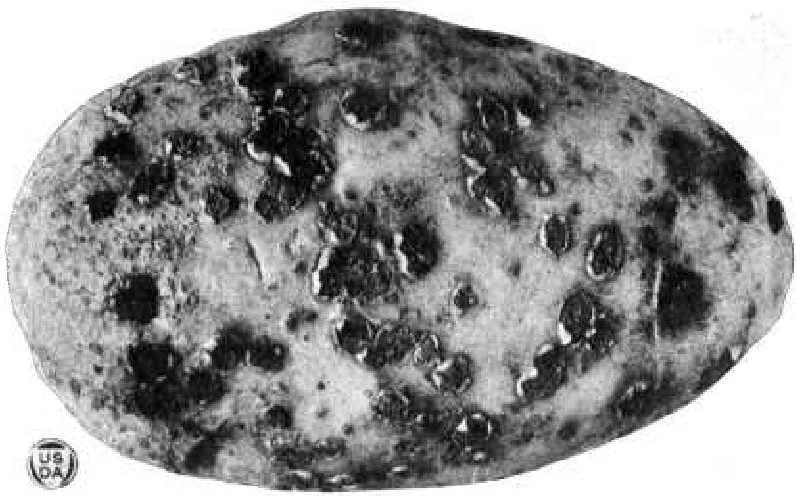

FIG. 19.—A potato showing the mature stage of powdery scab.

from year to year, depending on seasonal conditions. On the whole, this disease has not been found to present a serious menace to the national potato industry. It is caused by a slime mold fungus, *Spongospora subterranea* Johns., and differs very distinctly in its appearance from common scab. The individual spots are more nearly circular in shape and on the average are smaller in diameter than the common scab spots. When fully mature they represent open pustules filled with a brown more or less powdery mass of spores and broken-down tissue and surrounded on the edge by fringed remnants of the skin. In the immature stage these spots are closed and somewhat raised, dark on the outside and brown or olive brown on the inside. The closed stage of powdery scab has sometimes been called skin-spot (fig. 20). The fungus lives in the soil, and infection takes place during the growth of the tubers. Under some conditions the diseased seed tubers may introduce powdery scab into clean soils. Although affected stock is fit for table use it has a lower market value because of its unsightliness and because of the waste resulting from deep paring. Serious damage

occurs when powdery-scab pustules become infected with secondary rot-producing organisms. The injured tissues at the scab lesions offer an easy entrance for these organisms, and a dry rot follows (fig. 21).

Control.—The affected tubers should not be used for seed purposes in localities with cool moist climates, since these conditions favor the development of the disease. Seed treatment will reduce the infection present on the tubers, but will not prevent the infection originating from the soil whenever seasonal conditions favor it. Local experience will often enable the grower to avoid planting potatoes on soil types favorable to powdery scab.

FIG. 20.—A potato showing "skin-spot," or the closed-pustule stage of powdery scab.

RHIZOCTONIA SCAB AND SCURF.

Diseases of various crops due to the fungus Rhizoctonia are widely distributed in the United States. Two different species of Rhizoctonia have been found on potatoes in this country. However, the most common forms of Rhizoctonia injury which are here presented are caused by one species only (*Rhizoctonia solani* Kühn). The other species (*R. crocorum* (Pers.) DC.), known commonly as the violet root-rot fungus, occurs only in a few localities, principally in the Northwest, causing a little tuber rot and an injury to roots and stems. Perhaps the most prevalent manifestation of Rhizoctonia on the potato tuber is the so-called black scurf (fig. 22). It consists of hard black to brown particles, adhering firmly to the skin of the tuber and greatly varying in size and shape. These particles, known as sclerotia, are composed of an extremely close weft of fungous threads and represent the winter or resting stage of the fungus. They are harmless to the potato in this stage and unless present in large numbers do not injure the sale of tubers for table purposes, though in cars with high humidity the growth of mold which comes

FIG. 21.—A potato showing a dry rot following powdery scab.

from these sclerotia sometimes may affect the sale of a lot. When introduced into the soil on seed tubers these sclerotia produce an abundance of young threads, which attack the young shoots, stolons, and tubers of the new crop. Stems and stolons are frequently girdled, and in severe cases poor stands and low yields often result. Repeated severance of the stolons may lead to the production of a great number of small unmarketable tubers, or "little potatoes." Injuries to the underground portions of stems and roots often lead to the formation of aerial tubers in the axils of the leaves. Another common result of tuber attack by Rhizoctonia is russet scab (fig. 23). In this case the fungus causes the death of the superficial layers of the skin or follows natural cracks, and in consequence a white-skinned variety may take on a russet appearance. In the worst cases the tubers may become deformed. When the Rhizoctonia attack is associated with preceding insect injuries the damage to the tuber is still greater. Following flea-beetle injuries Rhizoctonia is likely to produce deep cracks and furrows and also to penetrate the tuber along the insect punctures. When invading wireworm holes Rhizoctonia widens and deepens the pits and channels (fig. 24). Wireworm holes free from Rhizoctonia infection represent comparatively clean cylindrical pits or tunnels having only a thin corky lining inside. They extend sometimes very deeply into the flesh of the tuber. In this respect they are quite different from the tuber-moth channels, which cover the surface of the affected potato with curved ridges running in various directions. Lenticels, or breathing pores, also may be invaded by Rhizoctonia. It may attack these openings and produce small dry pits on the tuber. The fungus also lives in the soil and may attack the new crop even when clean tubers are planted.

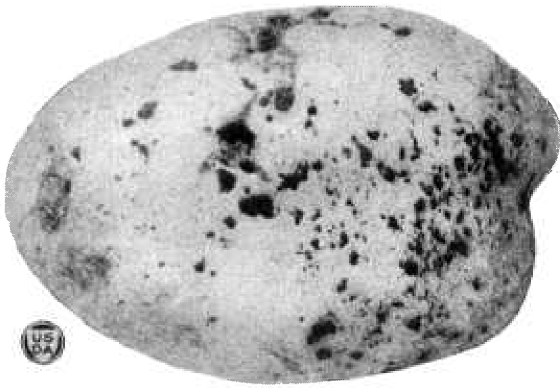

FIG. 22.—Black scurf. A potato covered with black sclerotia of Rhizoctonia.

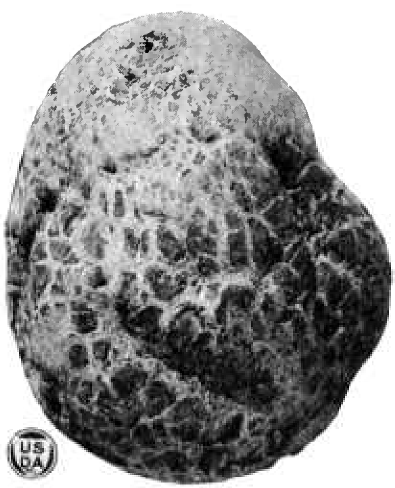

FIG. 23.—A potato showing a type of russeting frequently caused by Rhizoctonia.

Control.—No means are known of exterminating the scab and scurf fungus from the soil. However, many fields produce very little Rhizoctonia injury, and care should be taken not to introduce Rhizoctonia with the seed. Treatment of seed potatoes has been reported from many localities as greatly reducing the amount of Rhizoctonia infection in comparison with untreated seed. So far as this disease is concerned, corrosive sublimate has proved in many instances more efficient (see p. 6) than the standard formaldehyde treatment. However, recent experiments conducted by the Iowa Agricultural Experiment Station indicate that both hot and standard formaldehyde may be as effective in controlling Rhizoctonia as corrosive sublimate. The Idaho Agricultural Experiment Station reports that the efficiency of both the corrosive sublimate and the hot-formaldehyde treatments for the control of Rhizoctonia is greatly increased by first sprinkling the potatoes with water and covering them for 24 or

FIG. 24.—A potato showing deep cracks and furrows caused by Rhizoctonia following insect injuries.

48 hours with canvas. Since large sclerotia are penetrated with difficulty by any disinfectant, tubers covered with such sclerotia should be discarded, as the fungus inside of these pits may not be reached by the fungicide.

SILVER SCURF.

This disease (fig. 25) appears to be quite generally distributed over the United States. It is caused by a fungus, *Spondylocladium atrovirens* Harz, which kills the superficial layers of the skin but is not known to cause rot. The affected portions of the skin take on a silvery appearance, which is best seen when the tubers are wet. These areas may be small or large, in severe cases extending nearly over the entire tuber. The disease becomes more pronounced in storage, especially under moist conditions, which favor the formation of a superficial sooty layer composed of the fungous growth. Badly affected tubers are likely to shrivel more rapidly than sound tubers. The parasite lives in the soil, where the infection of the new crop takes place. The table value of the stock is not impaired in mild cases, though badly affected and shriveled tubers may become practically unsalable.

Control.—Disinfection apparently does not kill the fungus below the surface layers of the skin. No measures are known to kill the germs in the soil. Seriously affected tubers should not be planted.

POTATO WART.

Fig. 25.—A potato affected with silver scurf.

This dangerous disease (fig. 26), which has been known for many years in certain European countries, particularly England and Germany, was discovered in the United States in 1918. It is definitely known to occur only in certain counties in Pennsylvania, West Virginia, and Maryland, which are now under strict quarantine to prevent further spread. Fortunately, thus far no commercial potato-growing sections are known to be infested. The disease is characterized by warty, cauliflowerlike outgrowths originating at the eyes of the tubers. It is due to the fungus *Synchytrium endobioticum* (Schill.) Perc., which enters the outer layers of the eyes, exerting a powerful stimulus to abnormal growth. If infection takes place during the early part of the season, the entire tuber may be converted into a worthless spongy mass. Similar warts may occur on stolons and other underground portions of the potato plant. Young warts usually have the color of the affected parts of the potato plant, later turning light brown and finally dark brown or black after decay sets in. The fungus is able to live in the soil for at least eight years, even if potatoes are not planted every season.

Fig. 26.—A potato showing a pronounced case of wart infection.

American varieties of potatoes show a great range of resistance and susceptibility to this disease. Some of the best varieties, such as Irish Cobbler, Green Mountain, and Spaulding Rose, are entirely immune, and such varieties alone are being grown in the infested regions. Unfortunately there is as yet no wart-immune variety of the Rural group.

Control.—As there is no practicable way to eradicate the wart infestation from the soil, a strict quarantine of the infested areas is being maintained. Under these restrictions no potatoes can be

shipped out of the infested localities. Effective control to eliminate crop losses in infested areas is practicable through the use of such immune varieties as are adapted to the locality.

EELWORM GALLS.

The eelworm, or root-knot nematode, *Heterodera radicicola* (Greef,) Müll (figs. 27 and 28), has become a serious factor in potato culture in the West and to a certain extent in the South, not only through the direct injury to the potato crop but because infested potatoes are one of the most effective means of spreading the disease to the many other crops that are subject to it. Owing to this fact some States have resorted to quarantine restrictions on shipments of the diseased stock. These parasites attack the tubers and produce swellings, or galls, varying in shape and size. The individual galls are more or less round; but they frequently run together, and then the tuber takes on a knotty and irregular appearance. When cut, such potatoes show a line of tiny glistening spots (the female nematodes) and slightly discolored watery areas just beneath the swellings (fig. 27). Unlike the potato-wart protuberances, the eelworm galls are never confined to the eyes or growing tissues, but are scattered promiscuously over the tuber. In addition, the eelworm swellings contain live nematodes, the pear-shaped females and the wormlike males. The root-knot nematode attacks a large number of commonly cultivated plants, causing immense damage in some instances. Feeding roots when seriously attacked by the nematodes are unable to function properly, if at all, and the growth of the plant is checked. Moreover, the watery tissues of the galls are subject to the attacks of fungi and bacteria, which contribute to the destruction and consequently lead to a great reduction of yield. The root-knot nematodes are able to spread in the soil to uninfested areas, though very slowly. However, they can be easily carried from field to field by running water or by soil clinging to agricultural implements, the hoofs of animals, and the feet of

FIG. 27.—A potato severely affected with eelworms, showing the irregular knotted appearance of the outside of the tuber.

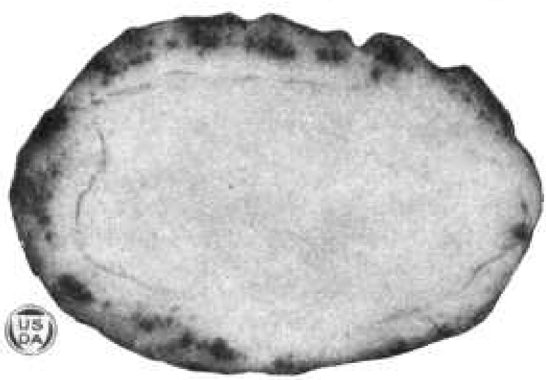

FIG. 28.—A potato affected with eelworms, showing its internal appearance.

man. They also may be transported from one locality to another in the roots of growing plants or with tubers, bulbs, and nursery stock. Fortunately, some plants, as, for example, barley, corn, rye, peanuts, timothy, and a number of other crops, are known to be free from the attack of this disease and may be advantageously used in crop rotations.

Control.—Eelworm-infested potatoes should never be planted or shipped to another part of the country, as they may carry the disease to uninfested regions. Infested soils must be rotated in crops not subject to this pest. Detailed descriptions and recommendations for control are given in Farmers' Bulletin 1345, Root-Knot: Its Cause and Control.

OBSCURE AND NONPARASITIC TROUBLES.

Two distinct classes of potato-tuber troubles are included in this group, a few the cause of which is not at present definitely known and others which are primarily or exclusively due to unfavorable environmental conditions, such as temperature, aeration, and moisture. However, both classes have in common the fact that, so far as our knowledge goes, they are not caused by any known fungus or bacterium.

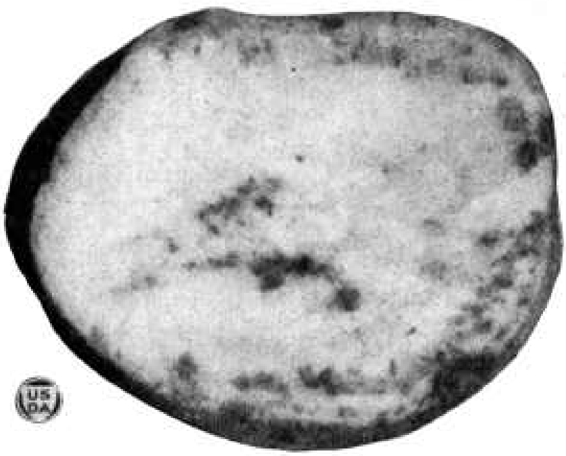

Fig. 29.—A potato affected with internal brown-spot.

INTERNAL BROWN-SPOT.

This disease (fig. 29) is characterized by irregular, dry, brown spots or blotches scattered through the flesh of the potato and not restricted to the water vessels, as in the vascular diseases. This trouble is believed to be not of a parasitic nature, because the spots consist of groups of dead cells apparently free from fungi or bacteria. Likewise, no definite foliage trouble has so far been attributed to the planting of tubers showing internal brown-spot. Frequently the disease appears to be associated with dry soils or lack of water at some period during the growth of the tuber and seems to be worse on some varieties than on others.

Control.—No measures have been worked out which will prevent the occurrence of internal brown-spot in the field. The best cultural conditions may, however, ward off or at least reduce the severity of this trouble, as is also the case with many other diseases. If sound seed potatoes are obtainable, it is advisable on general principles not to plant badly affected tubers, as they are likely to produce weak plants.

NET NECROSIS.

As the name indicates, the outstanding feature of net necrosis (fig. 30) is the presence of a network of dead fibers, brown to dark brown in color and sometimes extending throughout the flesh of the tuber. In mild cases it may be limited to only a small portion of the tuber, usually at the stem end, but in typical cases it is never confined to the vascular ring. According to some recent investigations this trouble appears to be a tuber symptom of leaf-roll, though not all leaf-roll plants produce tubers with net necrosis. However, when potatoes showing net necrosis are planted, leaf-roll symptoms are much more severe in the field.

FIG. 30.—A potato affected with net necrosis.

Control.—Roguing to eliminate leaf-roll plants in the field may be expected to reduce materially the possibility of net necrosis in the tubers. Potatoes affected with net necrosis should not be planted.

HEAT AND DROUGHT NECROSIS.

Heat and drought necrosis (fig. 31) has been noted in tubers grown in light, hot soils in the hot arid potato sections of the United States. It has been noted especially in the early crop grown in the volcanic-ash soils of Idaho and seems to occur in tubers which are allowed to lie in the hot soils after the vines begin to die. It is marked by the death and a golden yellow to brown discoloration of the water vessels of affected tubers, this being most pronounced in the ring tissues, either at the stem or bud end, and in the tissues between the ring and the tuber surface. It thus differs from net necrosis, which it somewhat resembles both in color and in distribution. Discoloration at first is restricted to the water vessels but after a time it spreads slightly to surrounding tissues, and the color changes from golden yellow to a light or dark brown. Sometimes in light-skinned varieties the discolored tissues give a darkened appearance to restricted areas of the surface. Upon cutting, it is found that the discolorations are not due to a solid dark mass of tissue, as they appear to be, but rather to the discolored strands, which impart a dark hue to the tissue under which they lie.

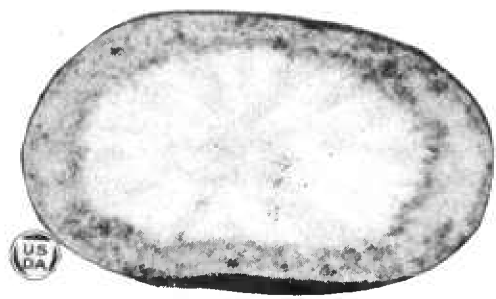

FIG. 31.—A potato affected with heat necrosis.

Control.—Control involves keeping the soil moist, cool, and shaded and in digging the tubers as soon as the vines begin to die if the soil is light and the weather hot.

FREEZING INJURY.

If exposure of potatoes to freezing temperatures leads to ice formation in the tissues, it may cause a variety of symptoms known as freezing injury. Sometimes these symptoms are general and readily apparent externally; at other times they are localized internally and are visible only upon cutting. The latter type is known as freezing or frost necrosis, while the former is known as freezing. Both types of symptoms can be detected only after thawing.

Tissues killed by freezing are very wet and usually become infected with bacteria, which cause a foul-smelling slimy or sticky rot if they thaw in a warm humid atmosphere (see "Slimy soft-rot"), or they may dry down to a mealy or tough leathery granular chalky mass if they thaw in cold or dry air. In tubers in which only one side is frozen the killed portion frequently is sharply set off from the un-

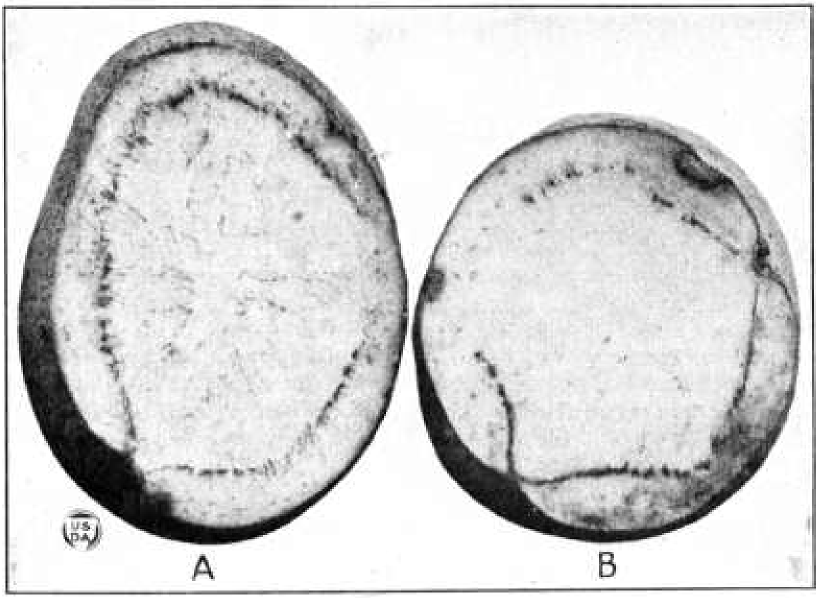

FIG. 32.—Potatoes showing freezing necrosis: *A*, The ring and net types; *B*, the ring and blotch types. The upper blotch was caused by freezing and bruising.

affected area by a purplish or brown line of corky tissue. Often Fusarium tuber rot sets in before the unaffected cells are sealed by the corky layer. See "Fusarium tuber rot."

Generally, however, freezing necrosis is marked by decided discolorations, of which there are several types. One, the ring type (fig. 32, *A* and *B*), is limited to the vascular ring and immediately adjoining tissues. Another, the net type (fig. 32, *B*), is marked by more or less blackening of the water vessels and the finer strands which extend from them into the interior pith and outer tissues. Both types frequently are restricted to the stem end. Finally, there is a blotch type (fig. 32, *B*), marked by irregular patches ranging in color from an opaque gray or blue to sooty black, which may occur everywhere in the tuber, though they are found generally in the water vessels and in the tissues outside of these. When these blotches are in the outer tissues they may be apparent externally in

clean tubers with white skins. This is the only type of freezing necrosis which may be visible externally. Tubers affected with any or all of these types of freezing necrosis generally shrivel or wilt more than nonaffected tubers. Excessive shriveling alone, however, can not be relied upon as a sign of freezing necrosis.

If tubers are exposed to low temperatures, but not low enough to cause ice formation, sugars accumulate and the tubers become sweet. This sweetness disappears if these tubers are kept at temperatures above 40° F. Frozen tissues, however, are no sweeter than uninjured ones. Sweetness of tubers, therefore, is not a sign of freezing.

Potato tubers will not freeze at 32° F. The critical temperature, that is, the temperature at which ice begins to form, lies between 29.5° and 26.6° F. It is impossible to forecast the critical temperature for an individual tuber, because there is variation in the individual susceptibility of tubers to freezing. The length of exposure to critical temperatures also is an important factor. Tubers which are severely affected usually rot in the soil before sprouting. For this reason it generally is not advisable to plant tubers showing severe freezing necrosis. Potatoes showing only slight freezing necrosis may ultimately produce normal plants, but on general principles they are not recommended for planting if sound potatoes can be obtained.

FIG. 33.—A potato showing sun-scald injury.

Control.—To prevent freezing injury tubers should not be exposed to temperatures below 32° F.

SUNBURN AND SUN SCALD.

These troubles are caused by the exposure of tubers to the sun during growth or after digging, either in the field or in transit or storage.

Sunburn is a greening in response to exposure to light and does not involve the killing of the affected tissues. It frequently occurs in growing tubers. It is accompanied by a pungent taste and renders tubers unpalatable for most people and even poisonous for a few. In cases of long exposure the outer tissues turn deep green and the underlying ones a greenish yellow or a deep yellow. Such tubers usually wilt and shrivel abnormally. Tubers when dug immaturely turn green or yellow and shrivel more readily than mature ones with well-developed cork layers.

Frequently the exposure to sunlight and accompanying high temperatures leads to the killing of the cells, which is known as sun scald (fig. 33). Often the affected tubers become watery and turn brown throughout, or at least to a considerable depth. In other cases, freshly scalded areas externally appear blisterlike and have a

metallic color, the underlying tissues being quite watery. Such areas may dry out and appear chalky and granular or hard and leathery. Most frequently, however, they are attacked by bacteria which cause foul-smelling bacterial rots or by organisms which cause leak. See "Leak" and "Slimy soft-rot."

Control.—The only possible control of sunburn and sun scald is to prevent the exposure of tubers to the sun for prolonged periods of time.

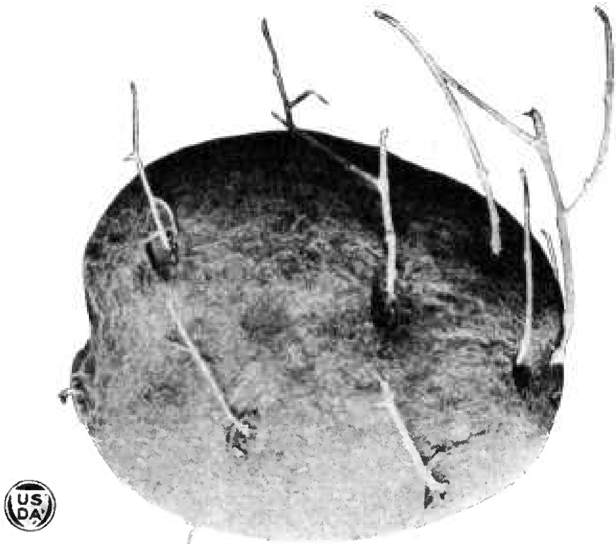

FIG. 34.—A potato affected with spindling-sprout.

SPINDLING-SPROUT.

This disease (fig. 34) is characterized by abnormally slender and feeble sprouts. It indicates a constitutional weakness of the tuber and is known to occur wherever potatoes are grown. It has been noted that potatoes affected with net necrosis are liable to produce spindly sprouts, though very often tubers which are firm and apparently sound on the outside as well as in the inside will also produce such abnormal growth. In these cases the disease can be detected only when the sprouts are formed. The table quality of spindling-sprout potatoes which otherwise show no disease or injury may not be impaired, but affected stock can never produce normal plants or a good yield, and it is likely to become worse with each new generation.

Control.—If seed tubers are sprouted at the time of planting, all tubers showing spindling-sprout should be discarded. If the disease appears in the field, the affected plants should be pulled out, especially in the seed plat.

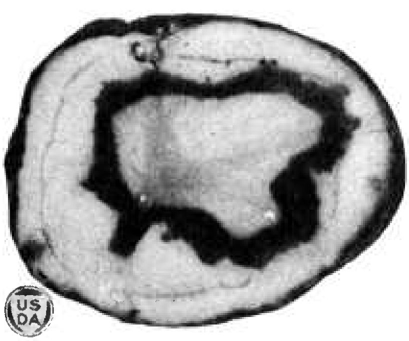

FIG. 35.—A potato showing black-heart.

BLACK-HEART.

Black-heart (fig. 35) is a result of asphyxiation of the tissues of the potato tuber. It takes place when the temperature is too high or when ventilation is so poor that the supply of oxygen is inadequate, or under various combinations of such conditions.

The symptoms of black-heart vary, depending upon whether the uninjured tubers were exposed to high temperature and a normal

air supply or to high, low, or normal temperatures with an insufficient air supply. In the former case, no external symptoms develop; in the latter, both external and internal symptoms appear. Asphyxiated tissues are easily invaded by bacteria and fungi, which hide the typical black-heart symptoms by causing various forms of watery or slimy decay.

The external symptoms of black-heart are moist areas on the surface, which may be purplish at first but turn brown or black within a short time. The internal symptoms are a dark-gray to purplish or inky black discoloration. Injured tissues when freshly cut soon after the injury are of normal color. Very shortly after the air strikes them they turn pink, then gray or purplish, and finally jet black. Sometimes all colors, save the pink, are found simultaneously in the same tuber; at other times only gray or brown colors are found, which is the case when tubers are heated above 130° F. or when they are deprived of all oxygen for considerable periods after death, as in water-logged soils or in flooded pits.

The discolored areas usually are sharply set off from the healthy tissues. The affected tissues are firm and even leathery if they have dried a little, quite unlike those affected with leak, which frequently show colors similar to those of black-heart.

Generally the discoloration is restricted to the heart of the tuber, but frequently it radiates to the exterior as well. It may also appear on the side of a tuber if this was exposed to a stove in a car or in storage or to the sun in the field while growing or after digging. The discolored regions may appear in zones in the outer parts of the tuber and be absent or less evident in the center. In advanced stages the affected tissues dry out and cavities result.

Control.—Since tubers will not develop black-heart at temperatures below 95° F. if given a good supply of air, control of the injury involves storage at temperatures below 95° F. with good ventilation. In stove-heated cars or storage places the potatoes near the stove should be protected by tin sheeting. The temperature in heated cars should not be allowed to go above 60° or 70° F. To prevent a shortage of oxygen, tubers should not be stored in solid piles more than 6 feet deep, even at a low temperature. They should not be left long in hot, light soils after the vines are dead or left lying near or on the surface after digging during hot weather. Flooding fields or packing hot, wet, and soil-covered tubers in closed containers, such as barrels, should be guarded against, since these methods may lead to black-heart.

HOLLOW-HEART.

This abnormality (fig. 36) consists of a more or less irregular cavity in the center of the tuber. This cavity varies in size and is usually lined by a thin brown layer of dead cells of the potato. It is caused by a growth that is too rapid and is common in certain moist seasons and on fertile soils in many rapidly growing varieties which tend to produce large tubers. Hollow-heart is not a decay and has no effect on the succeeding crop, though affected stock is undesirable for eating. It may readily be distinguished from black-heart, which has a conspicuously black lining of the cavity when present and black streaks throughout the flesh.

Control.—Since hollow-heart depends principally on seasonal and climatic conditions, the most practicable control measures at our disposal are those dictated by the experience of the grower as to the extent to which he can safely force the development of his crop, by fertilizers in the East, or by irrigation in the West. The choice of varieties is also a factor.

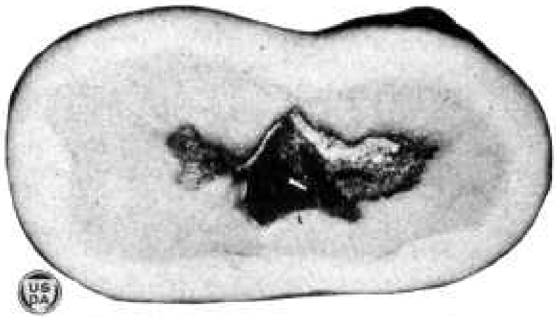

FIG. 36.—A potato showing hollow-heart.

GROWTH CRACKS AND SECOND GROWTH.

Deep cracks (fig. 37) on the surface of the tuber and knobs or second growth (fig. 38) may appear on all varieties in practically every potato-growing section. There is little experimental evidence as to whether some varieties or diseased strains of potatoes may not produce knobs and pointed ends even under the very best conditions of growth. Repeated field observations, however, disclose the fact that certain varieties, as, for example, Netted Gem, which shows an extreme tendency to form second growth, may be produced practically free from knobs and pointed ends as well as growth cracks. Frequently these deformities appear to be due to an uneven moisture supply through the period of tuber formation, as in the case of drought followed by a rainy spell. The drought causes the tubers to ripen and harden prematurely while the tops are still in full vigor. The abundance of moisture following the drought results in the renewal of growth, for which the hardened skin is incapable, and this leads to the development of cracks or the formation of knobs. In irrigated sections a similar effect may be due to improper irrigation when potatoes are left dry too long and then again are watered. In the case of the Burbank and Netted Gem varieties this practice is responsible for many misshapen pointed-end tubers. Field observations also indicate, however, that second growth and pointed ends are associated with abnormal vine symptoms. Growth cracks are usually covered with the normal cork layer and are not readily subject to decay. The knobs are mostly immature and are easily broken off. Occasionally they contract decay in the ground, but more frequently they offer an entrance to rot-producing organisms through the wound which is formed when

FIG. 37.—A potato showing growth cracks.

they are broken off. Leak in California and Fusarium rot in other parts of the country are the most frequent wound decays.

Control.—The abnormal growth of the tubers can not be prevented so far as it is due to natural climatic conditions except when proper soil moisture may be maintained in drought periods by frequent

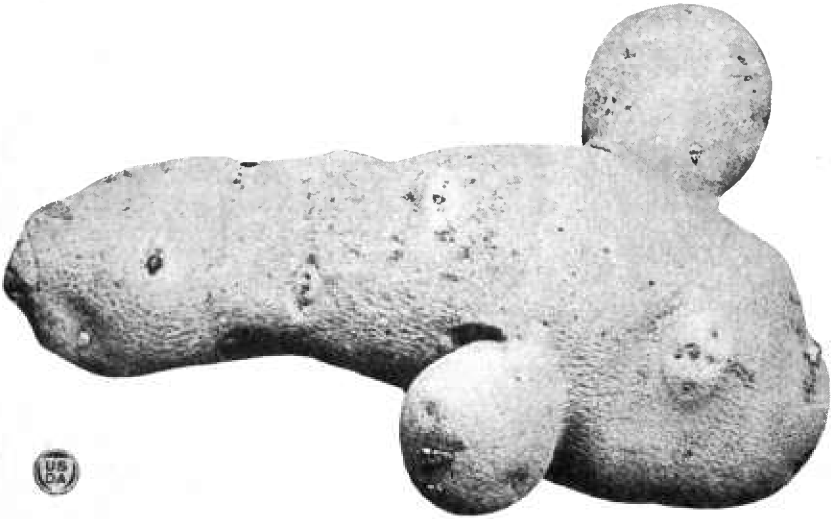

FIG. 38.—A potato showing second growth; pointed end and knobs.

cultivation. However, in the irrigated sections much trouble may be avoided by proper handling of the water supply. Care should be taken to avoid subsequent decay by not breaking the knobs off in handling.

FIG. 39.—A potato showing salt injury.

IMMATURITY.

Immature potatoes may readily be recognized by excessive wilting and excessive peeling of the skin in handling; also sometimes by a greenish tint under the skin. Late varieties in the North and especially southern potatoes dug for early marketing do not as a rule reach the stage of full maturity. Such potatoes are very susceptible to invasion by various rot-producing organisms, and especially by slimy soft-rot bacteria, if they are shipped in overheated cars or held in barrels under conditions of high temperature and humidity.

Control.—Immature potatoes should be handled very carefully to avoid bruising and skinning, which lead to shrinkage and decay. Table stock should be disposed of promptly. When immature potatoes are produced for seed they require not only careful handling to avoid bruising, but to prevent decay also require proper storage until the time of planting.

SALT INJURY.

Salt injury (fig. 39) is likely to result when potatoes in bulk or in sacks are piled in warehouses or in cars whose floors or walls are saturated or covered with salt following the storing or shipping of salt, salted hides, meats, or fertilizers. The parts of tubers immediately in contact with the salty surface are killed. Under pressure of the tubers above them the killed areas lose water and their surfaces flatten, the killed tissues being compressed. The dead tissues are of normal color at first, but soon turn brown and finally black. They may dry out completely into a hard, tough, leathery gray mass, or, as is usually the case, they may become infected with slimy soft-rot, which under favorable conditions not only destroys the entire tuber but also spreads to neighboring ones not in contact with the floor or walls.

Control.—This injury can be avoided by taking care not to place tubers in contact with surfaces which bear or are saturated with salt. False floors should be used in cars with salty bottoms.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

November 3, 1923.

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